C2 OF SPACE: THE KEY TO FULL SPECTRUM DOMINANCE

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Abstract

The Air Force Research Laboratory's Information Directorate (AFRL/IF) has a long and distinguished history of providing Command and Control (C2) technologies for the Air Force and the Department of Defense as "Rome Air Development Center" and "Rome Laboratory." As part of the reorganization that created the Air Force Research Laboratory in 1997, AFRL/IF was tasked to provide Information Dominance technologies to the warfighter. These critical aerospace technologies are the cornerstone to moving C2 capabilities into the next millennium. AFRL/IF's vision encompasses a three pronged approach to applying C2 to achieve Full Spectrum Dominance, anytime and anywhere. Conceptually, the three prongs are Global Awareness, Dynamic Planning and Execution, and Global Information Exchange. To achieve the vision, AFRL/IF has formed six Integrated Technology Thrust Programs (ITTPs) that apply C2 principles allowing the future Battle Manager's control of the battlespace. The first five ITTPs come under AFRL's Information Dominance thrust area: Configurable Command Center, Dynamic Command and Control, Consistent Battlespace Picture, Defensive Information Warfare, and Global Grid. The sixth ITTP, Real-time Sensor-to-Shooter, falls under the Precision Strike thrust area. This paper provides a brief background regarding Information Dominance and provides the goals, capabilities, and technologies required for each of the six ITTPs.

1. Introduction

Command and Control (C2) is the key enabler allowing U.S. Forces to achieve Full Spectrum Dominance[1] in the Ground, Air and Space mediums. A key to this supremacy is Information Dominance. It is this arena that poses the most challenges and opportunities to the Battle Manager. Figure 1 illustrates the traditional three-dimensional battlespace in which Battle Managers must have "total information dominance" to achieve the ultimate goal of Full Spectrum Dominance.

[1] Full Spectrum Dominance is defined as the ability of the Battle Manager to control the level of conflict over the complete breath of the N-dimensional battlespace (e.g., electromagnetic spectrum to Information Warfare techniques).

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Figure 1: Spectrum of Information Dominance

Today's battlespace hinges on an information centric environment. The winner of the next conflict will be the force that is first able to receive fast and reliable information about its opposition, as well as by presenting and conveying knowledge about the N-dimensional[2] view of the environment. In analyzing the battlespace, one needs to remember that this highly complex, fast changing environment increasingly centers around information. Figure 2 illustrates this complex relationship. The Battle Manager needs to dominate the total "information spectrum" in order to achieve victory. To do this, reliable information must flow freely within the system between the various forces (including our multinational/coalition partners), by effectively utilizing distributed data repositories coupled with intelligent applications. The end goal of this free flow of reliable information is to provide the Battle Manager the key elements required to control the battlespace.

[2] N-Dimensional view considers not only the traditional length, height, width of the battlespace but also such elements as time and the thought processes of the adversary

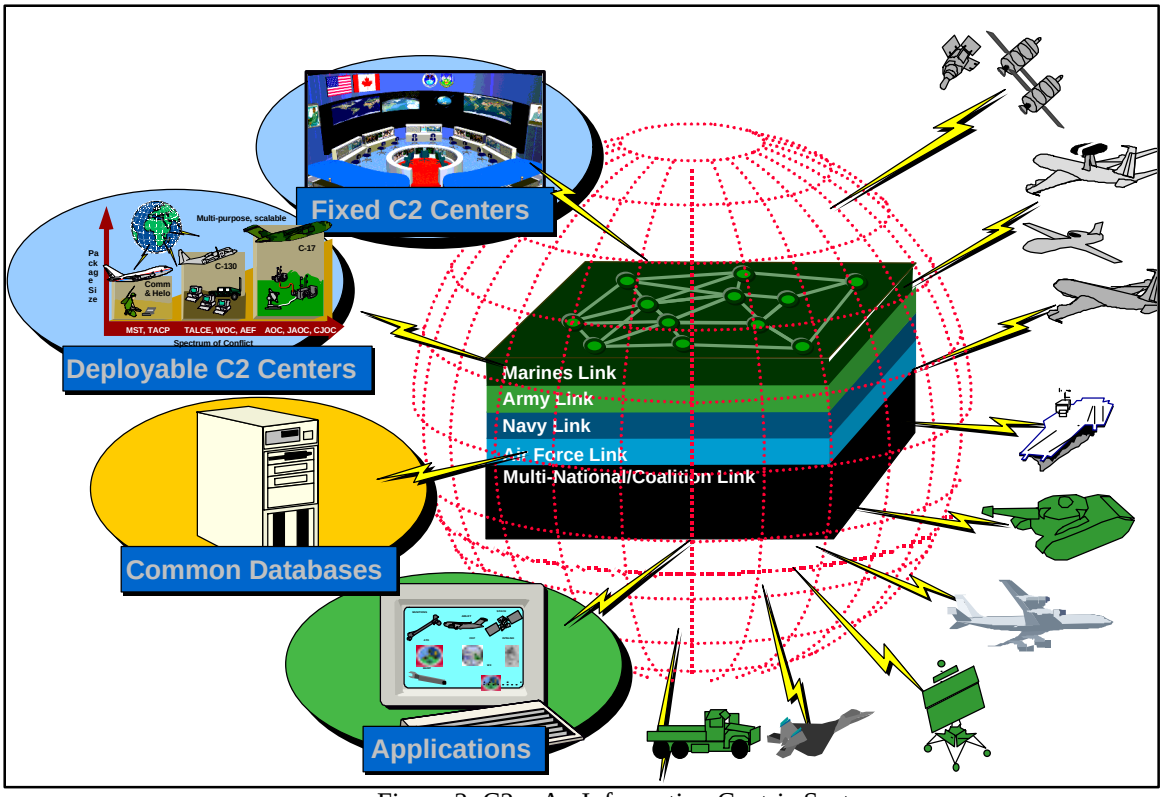

Figure 2: C2 – An Information Centric System

The capabilities in support of the warfighter must have certain attributes. In keeping with the Air Force vision, some key attributes required to support the warfighter are: a) affordable and easy to use; b) inherently joint and coalition capable; c) interoperable across all elements of the system; d) robust, reliable, secure and survivable; and, e) adaptable, providing shared tailored knowledge. Figure 3 illustrates a few of capabilities planned for the warfighter of the next millennium.

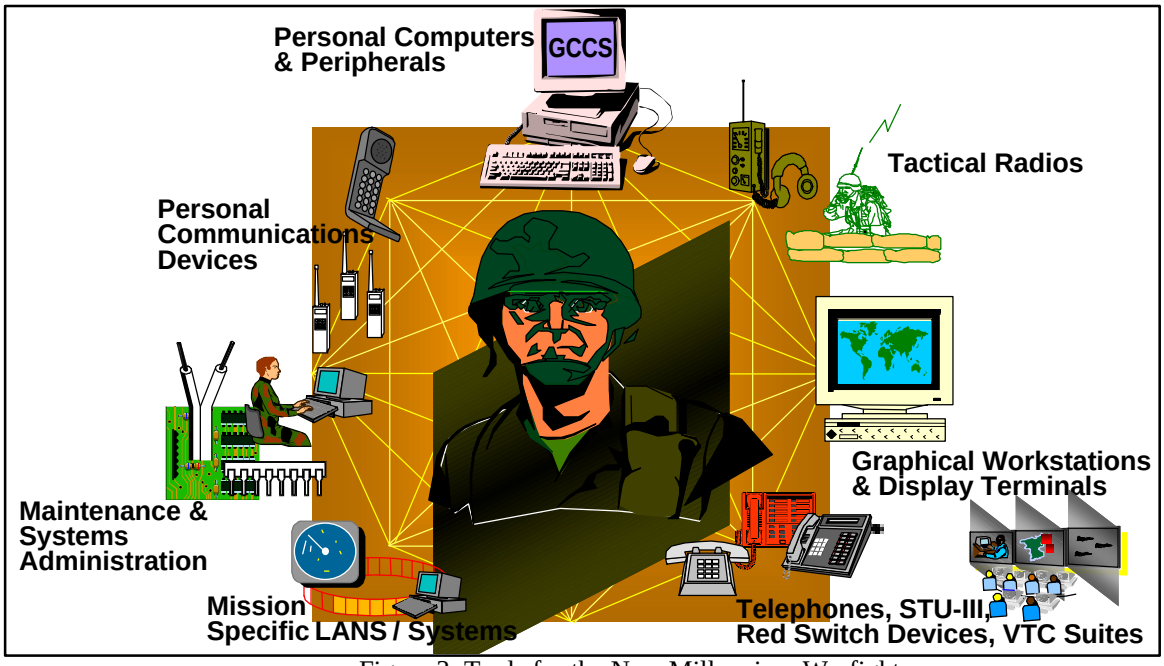

Figure 3: Tools for the New Millennium Warfighter

2. **Background**

In order to support the warfighter's information needs of the new millennium, AFRL/IF's vision has three thrusts: Global Awareness, Dynamic Planning and Execution and Global Information Exchange. These three combined thrusts will provide the Battle Manager the necessary C2 tools to achieve an "Information Dominance" capability. The key to broadening this capability into controlling the space environment is the ability to provide Knowledge on Demand: Integrated Information Systems to the warfighter. AFRL/IF's focus is to take and integrate all forms of information, process and intelligently analyze it, and present the right information in any format required by the warfighter, anywhere, anytime. This "Knowledge on Demand" provides for: fused, focused information versus raw data; distributed architectures in space, air, and on the surface; "web" style browser-based information on demand; distributed C2 and reachback capabilities; and, dynamic bandwidth on demand. The end goal is to provide the warfighter with an integrated information system necessary to completely control the aerospace environment. This end goal provides the foundation for the three thrusts within AFRL/IF and their stated goals.

The goals of Global Awareness are to increase the amount of data exploited; information fused with scalable resolution and accuracy as needed; and, storage and processing of information on aerospace platforms. Within Dynamic Planning and Execution, the goals are to increase the capability for predictive planning and preemption; integrated force management and execution; real time sensor to shooter operations; collaborative, distributed real time mission planning and training; and, collaborative/distributed battlespace simulation. The third prong, Global Information Exchange, has as its goals the increase in global communication to terrestrial, air and space assets; information warfare attack detection & recovery; assured and survivable networking; providing continuous 24 hr/day in-transit visibility; and, world-wide information on demand. This far-reaching global vision is depicted in Figure 4.

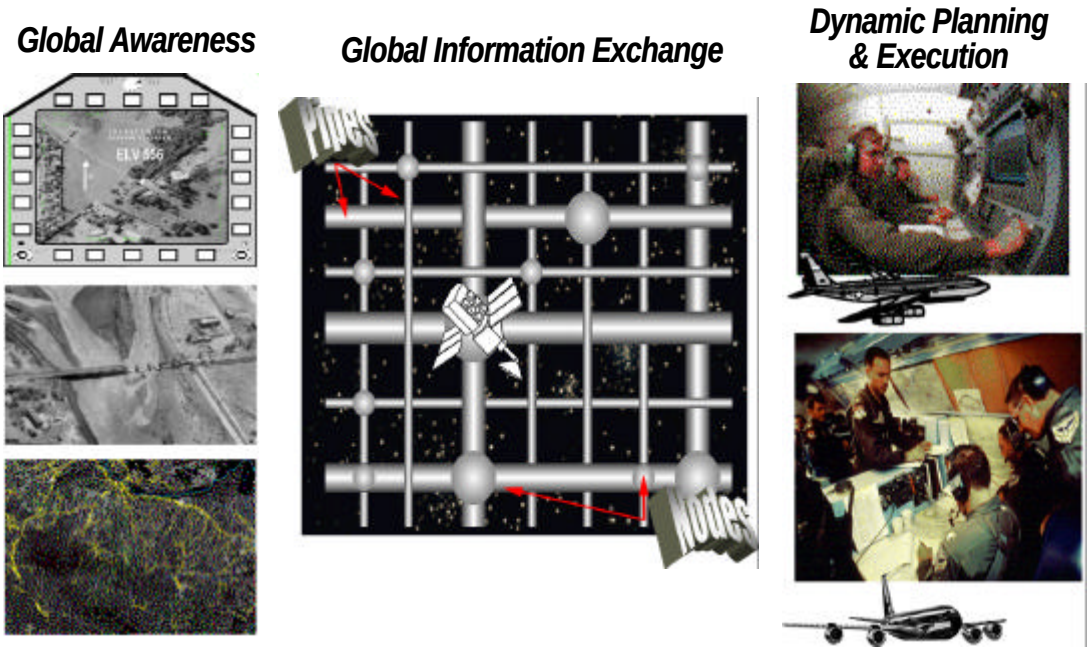

Figure 4: AFRL/IF Global Vision for Information Dominance

The core information technologies necessary to achieve this three pronged vision are:

a) Global Awareness: SIGINT Exploitation; Information Fusion; Mass Storage and Retrieval; Speech/Audio Processing; Information Data Handling; Image/Video Exploitation; and, Targeting Technologies.

b) Dynamic Planning and Execution: Distributed Information Systems; System Concepts Analysis; Modeling Methodologies; Virtual Prototyping; High Level Architecture for Modeling and Simulations; Real-time People/Equipment "in the loop"; Knowledge Based Systems Technologies; Planning; and, Database Management.

c) Global Information Exchange: Network Protocols; Network Management and Control; Distributed Information Infrastructure; Adaptive and High Performance Computing Systems; Multi-Level Security; Intrusion/Malicious Code Detection; Information Attack Mitigation; Hardware/Software co-design; Multi-band/Multi-Mode Radios; Low Probability of Intercept/Anti-Jam Waveforms; Emerging Hardware/Software Micro-Electro-Mechanical-Systems (MEMS); and, Satellite/Airborne Communications.

These three thrusts and their associated technologies play a prominent role in reaching the C2 vision for the Air Force. Figure 5 illustrates how AFRL/IF's three vision thrusts form the information foundation enabling Global Operations.

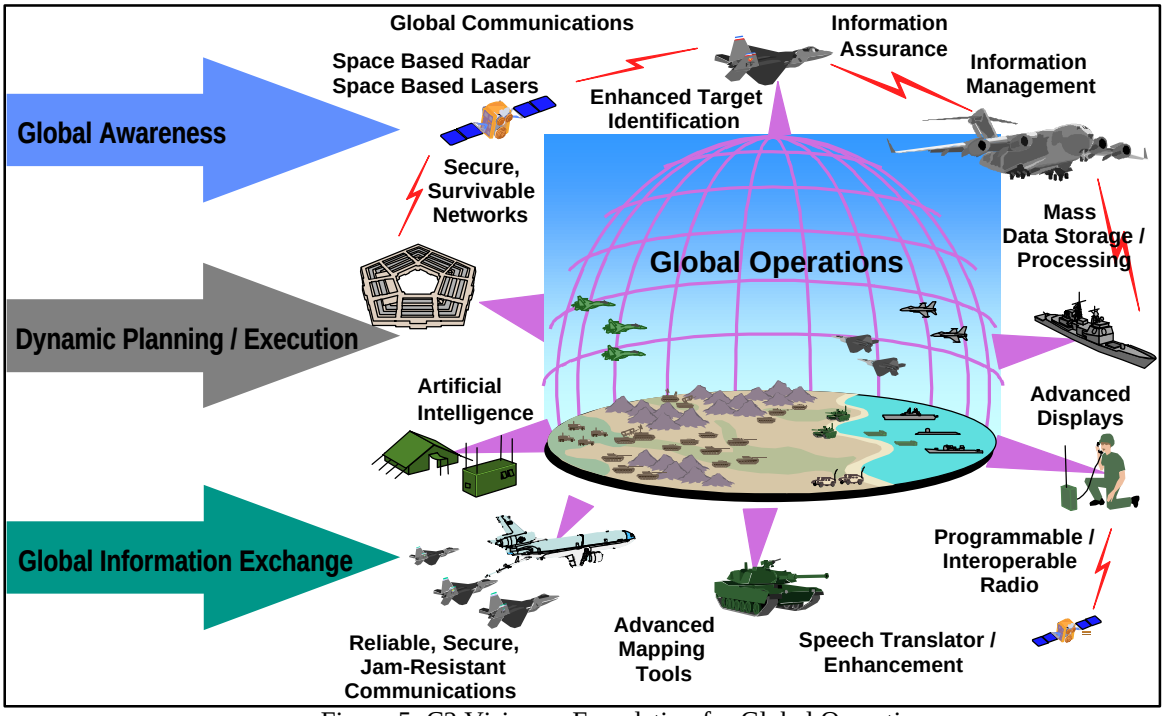

Figure 5: C2 Vision as Foundation for Global Operations

In order for this transition to be successful, a change from developing "stove-piped" systems to fully integrated ones must take place. AFRL/IF has embarked on converting from the old stovepipe development technologies to a synergistic view of technology insertion. This synergism will provide a truly integrated information system approach as shown in Figure 6. The manner in which AFRL/IF has taken to create a synergistic approach to C2 is the formation of Integrated Technology Thrust Programs (ITTPs).

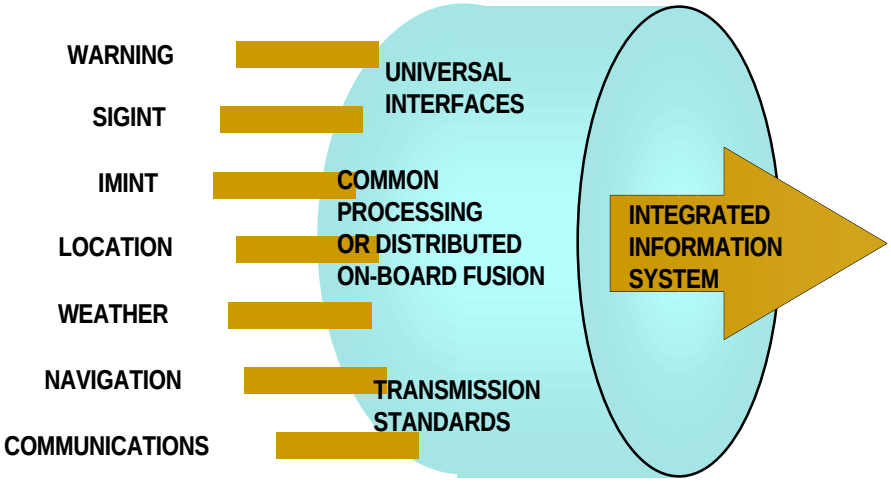

Figure 6: Integrated Information System Concept

3. **AFRL's Integrated Technology Thrust Programs (ITTPs)**

AFRL's Integrated Technology Thrusts (ITTs) have been developed to align along the Core Competencies of the Air Force as shown in Figure 7.

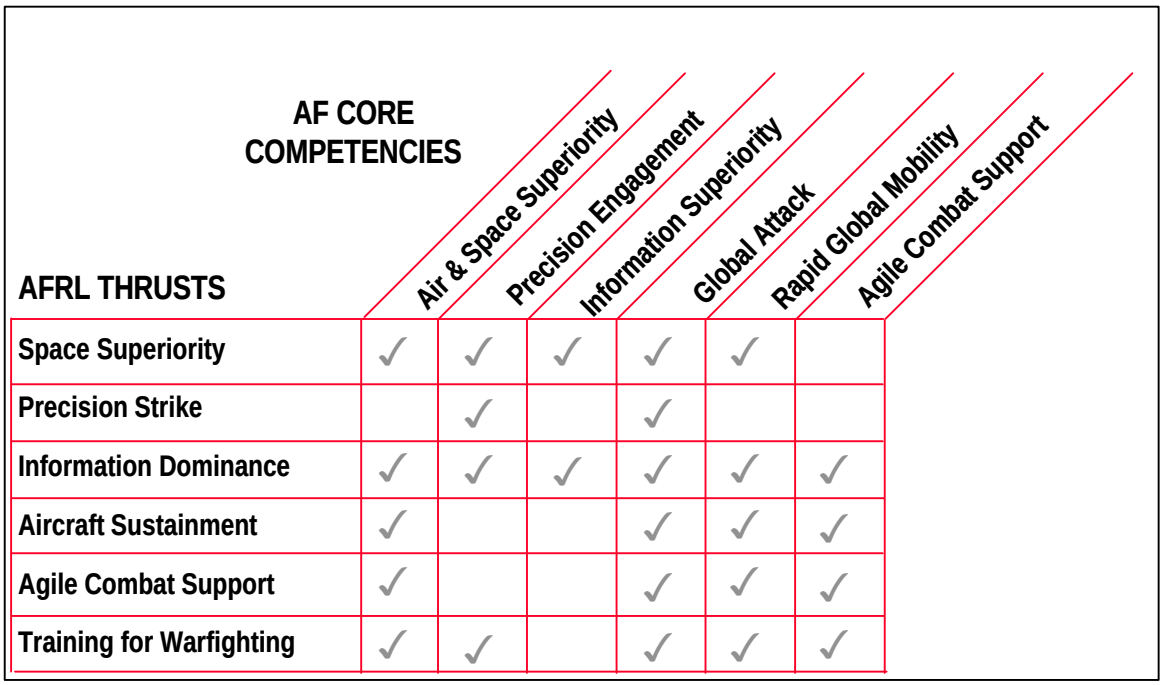

Figure 7: AFRL Thrusts as Part of AF Core Competencies

These ITTs were created to directly support the warfighter. Given the level of expertise of the various Directorates, the Information Dominance ITT (a cornerstone to reaching Full Spectrum Dominance of the battlespace), along with a portion of the Precision Strike ITT, have been assigned to the Information Directorate located in Rome, NY. Within AFRL's Information Dominance ITT, there are five ITT Programs (ITTPs): Configurable Command and Control Center, Dynamic Command and Control, Consistent Battlespace Picture, Defensive Information Warfare, and Global Grid. Within the Precision Strike ITT, AFRL/IF has been assigned the Real-time Sensor-to-Shooter ITTP. The linkages from the vision to the warfighter are shown in Figure 8. Illustrated is the link from AFRL/IF's three pronged vision of supporting the warfighter through the application of the ITTP concept.

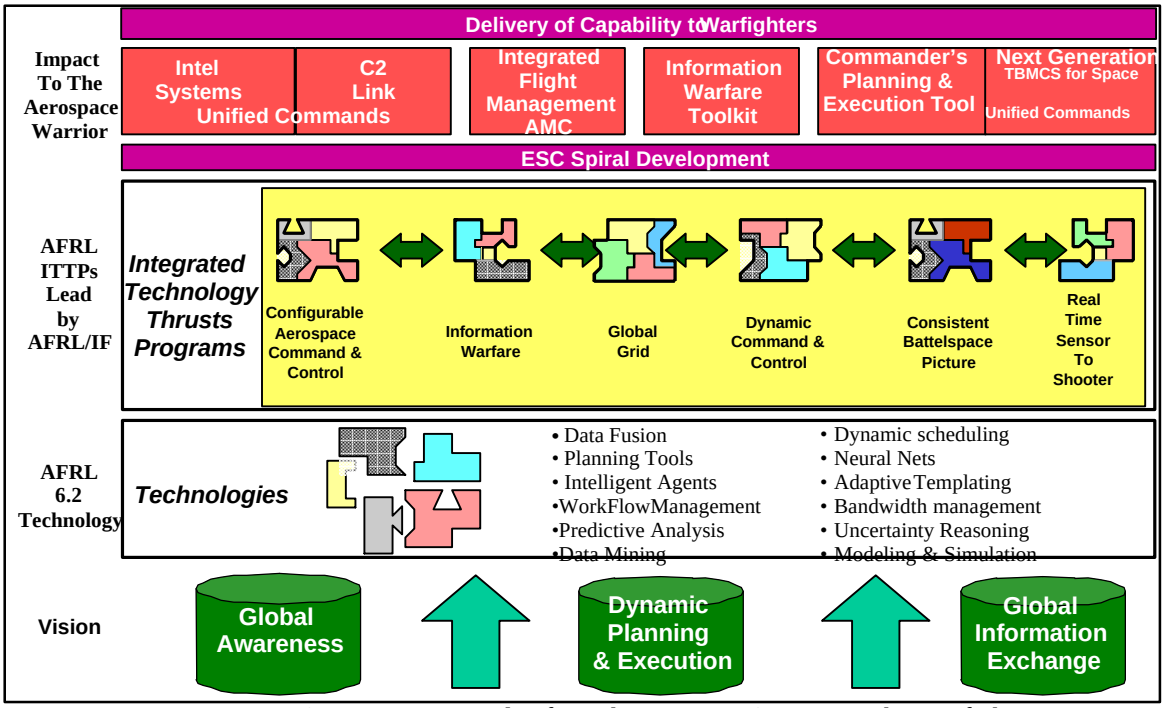

Figure 8: How ITTPs Bridge from the Vision to Supporting the Warfighter

The remainder of this paper describes the six Integrated Technology Thrust Programs (ITTPs) led by AFRL/IF. As a starting point, Figure 9 illustrates how the five Information Dominance ITTPs are working together as a single unit to address the three principle thrust areas of AFRL/IF. Within each ITTP area, this paper will describe the goals, capabilities, and inter-relationship with the other ITTPs, along with the required technology areas to be developed to ensure successful implementation.

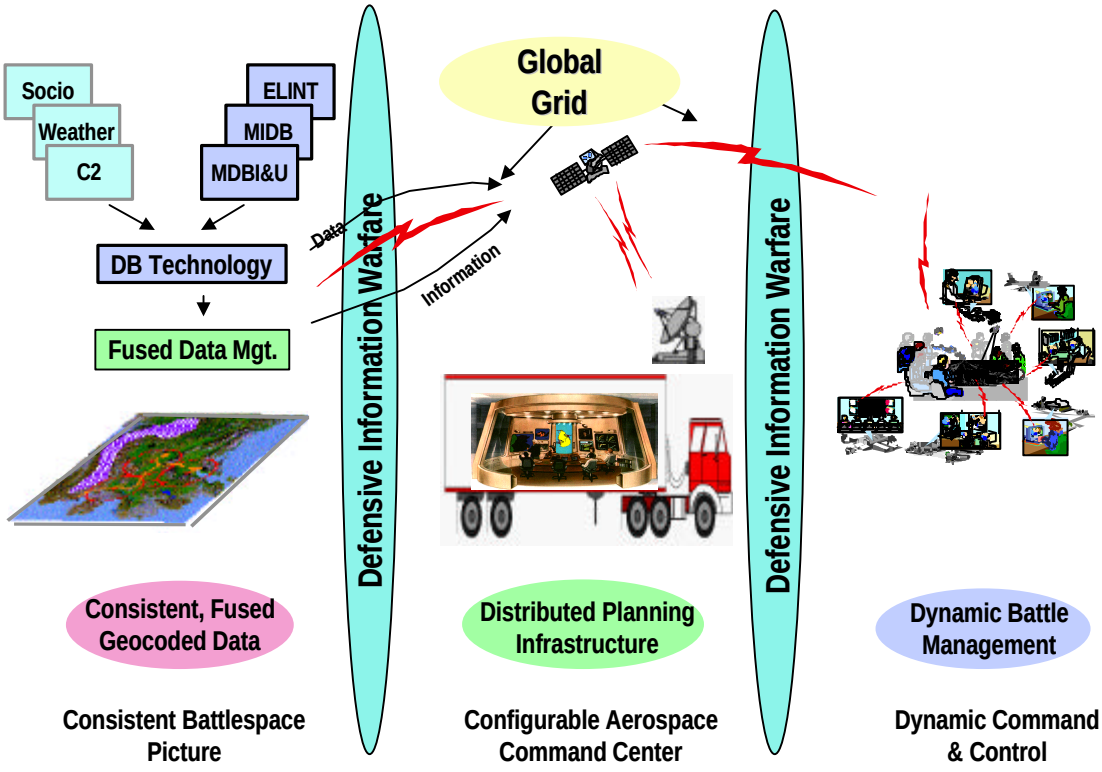

Figure 9: Integrated Technology Thrusts Inter-Relationships

4. **Information Dominance ITTPs Within AFRL/IF**

4.1 ***Configurable Aerospace Command Center ITTP***

Conceptually, the Configurable Aerospace Command Center (CACC) can be thought of as a scalable/adaptable infrastructure that can be assembled or tailored in a variety of ways to fit the needs of a mission. The CACC will provide mobile, scaleable and distributed command and control capabilities for forward deployed elements of the Expeditionary Air Force (EAF) and will include dynamically reconfigurable computing and communications architectures, enhanced collaboration environments, intelligent information management facilities, and embedded training and performance enhancement tools. The CACC capabilities will satisfy many of the emerging C2 requirements of Joint Vision 2010, the Air Force's Global Engagement doctrine and the new concepts of operation for EAFs of tomorrow. Prior to deployment, the Battle Commander determines which modules to "deploy" given the N-dimensional operational environment. Once there, the Battle Commander will have the ability to re-configure the CACC as the situation evolves. This capability provides a highly configurable and modular capability that will minimize the forward footprint, while maximizing the "assets" available to the Battle Commander. The basic concept of the Configurable Command Center is shown in Figure 10.

Figure 10: Configurable Command Center Representation

The goals for the Configurable Command Center ITTP are seamless system transition and reconfiguration based on mission requirements; adaptive (intelligent) switching interfaces to the Global Grid; integrated mission training, rehearsal, simulation, and real-time adaptive operations.

To achieve these goals, the following capabilities are being incorporated into the Configurable Command Center: variable-sized footprint for forward and support deployments; adaptive crisis response; in-transit Observe-Orient-Decide-Act (OODA Loop); automatic configuration for operational needs; and, integrated/adaptive mission training linked to user performance and needs.

Although the Configurable Command Center ITTP will rely on Industry standard distributed computing architectures, it has determined the following technologies require AF S&T investments in order to fully implement the concept: intelligent agents for configuration; application software portability; integrated (system, application) resource management; measures of effectiveness monitoring, analysis, and action.

The long-term goal of the Configurable Command Center is to create a “virtual world” for command and control. This “virtual world”, as shown in Figure 11, allows the Battlespace Commander to be virtually anywhere (e.g., a holodeck) yet still be able to effectively “reach out” and command troops anywhere in the battlespace.

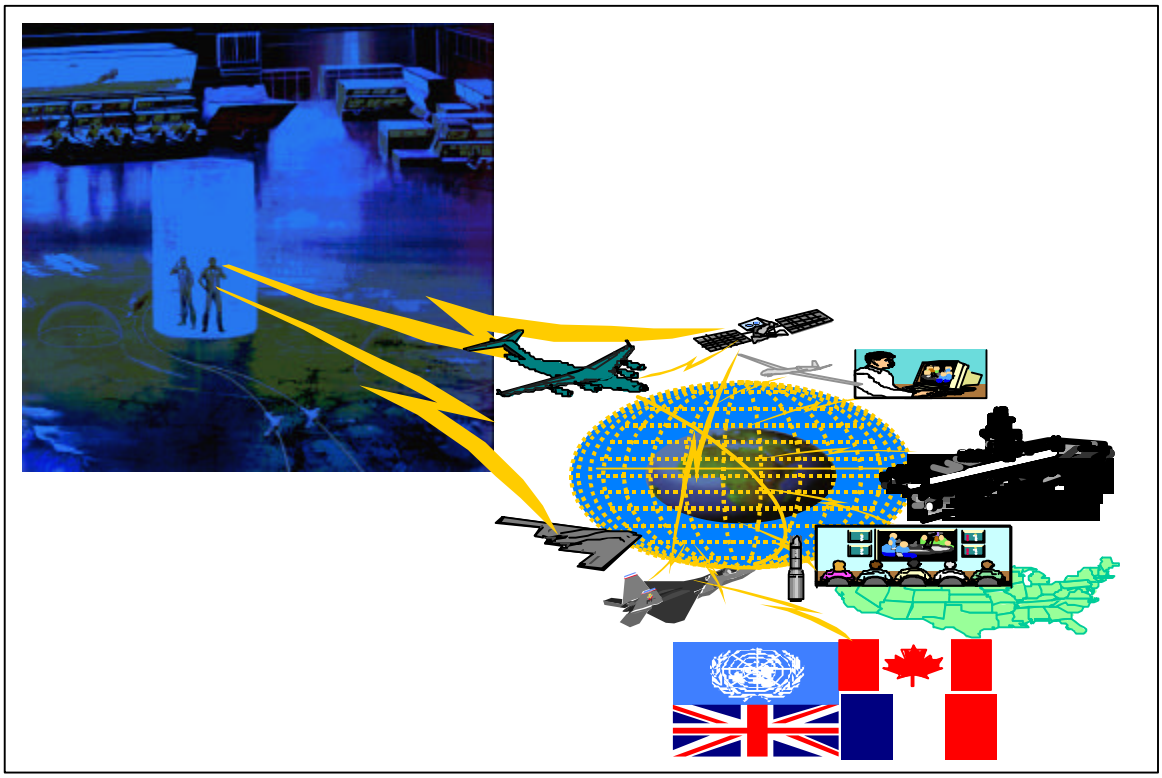

Figure 11: Holodeck of the Future

One manner in which the Commander and his/her staff can accomplish this “virtual world” is by utilizing virtual reality technologies. Figure 12 illustrates how a space controller can directly control space assets by simply “reaching out and touching the space vehicle”.

Advanced Displays and Intelligent Interfaces can provide enhanced visualization and natural interaction between the Battlespace Commander and the troops “in the field”. Figure 13 illustrates an artist’s view of how, by using virtual reality coupled with advanced displays, a Battlespace Commander can view and control the entire battlespace. However, with such a wide variety of information available regarding the battlespace, several forms of 3D stereoscopic displays and multi-modal human-computer interaction would be required to provide presentation and interaction with information in a much closer to “real-world” fashion.

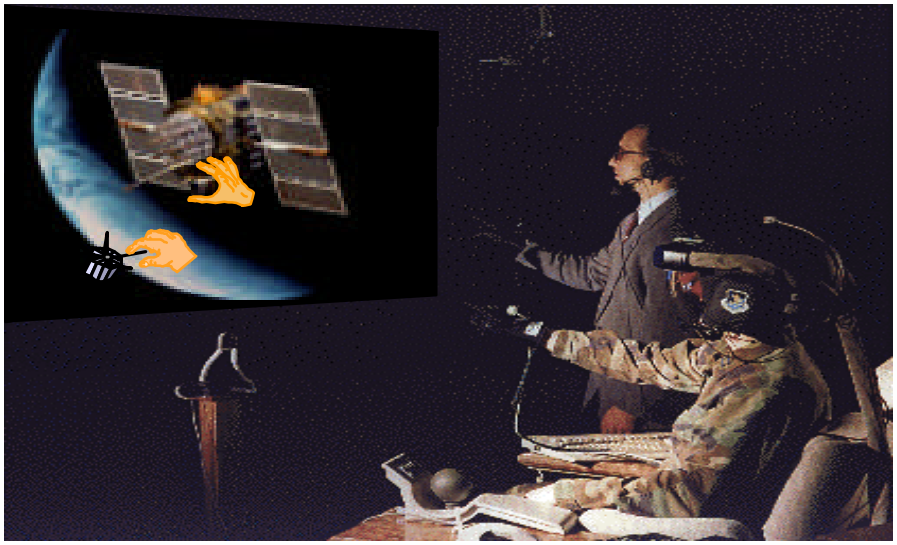

Figure 12: Virtual Reality for Command and Control of Space Assets

Figure 13: Future Warfighting using a “Virtual Battlespace”

4.2 ***Dynamic Command and Control ITTP***

The concept of Dynamic Command and Control is illustrated in Figure 14. Dynamic Command and Control will allow the Battlespace Commander the ability to control the entire N-dimensional battlespace anytime, anywhere and by any means.

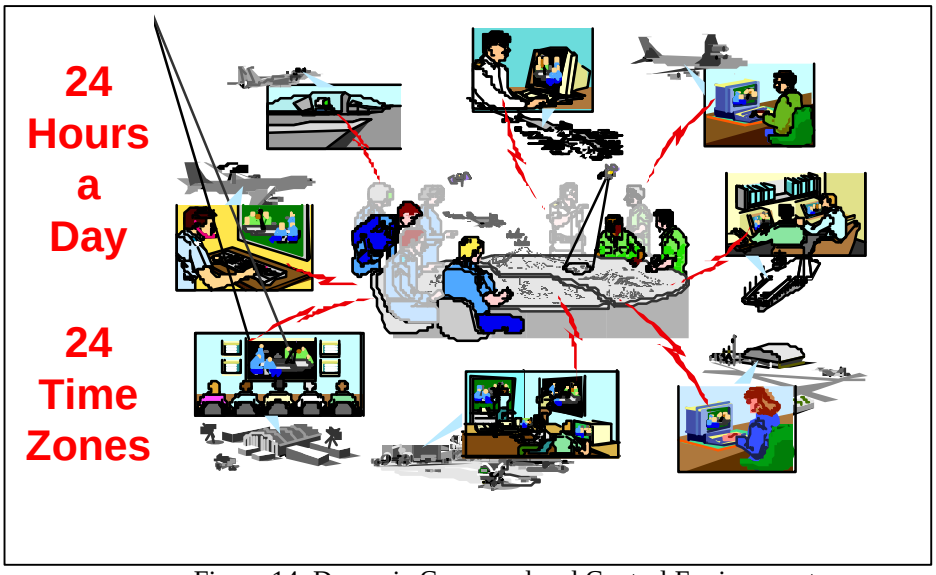

Figure 14: Dynamic Command and Control Environment

The goals of the Dynamic Command and Control ITTP are to: a) provide timely, flexible C2 across a spectrum of aerospace activities, such as, force support (logistics); b) provide force applications (shooter) and force enhancement (ISR[3]); c) aerospace control (defensive air); d) develop new C2 technologies which are highly flexible in an info-centric environment (refer to Figure 2); and, e) apply new C2 capabilities through a series of critical technology integration experiments designed with operational performance metrics.

To achieve these goals, the following capabilities would be required: just-in-time planning, controlling and execution of aerospace forces; enhanced force effectiveness through rapid situation prediction; universal access and integration of distributed information/knowledge sources; distributed and collaborative C2; and, adaptability in joint/coalition forces operations.

The Dynamic Command and Control ITTP has highlighted the following technologies that require AF S&T investments: knowledge based planning and scheduling; intelligent agent based systems; uncertainty information based planning; cross functional planning systems; and, high performance knowledge bases.

4.3 ***Consistent Battlespace Picture ITTP***

The Consistent Battlespace Picture, as shown in Figure 15, will allow the Battlespace Commander the capability of viewing/displaying reliable information from all sources in any format. It is envisioned that space assets will provide the vast majority of the required data depicted in Figure 15.

[3] ISR stands for Intelligence, Surveillance and Reconnaissance.

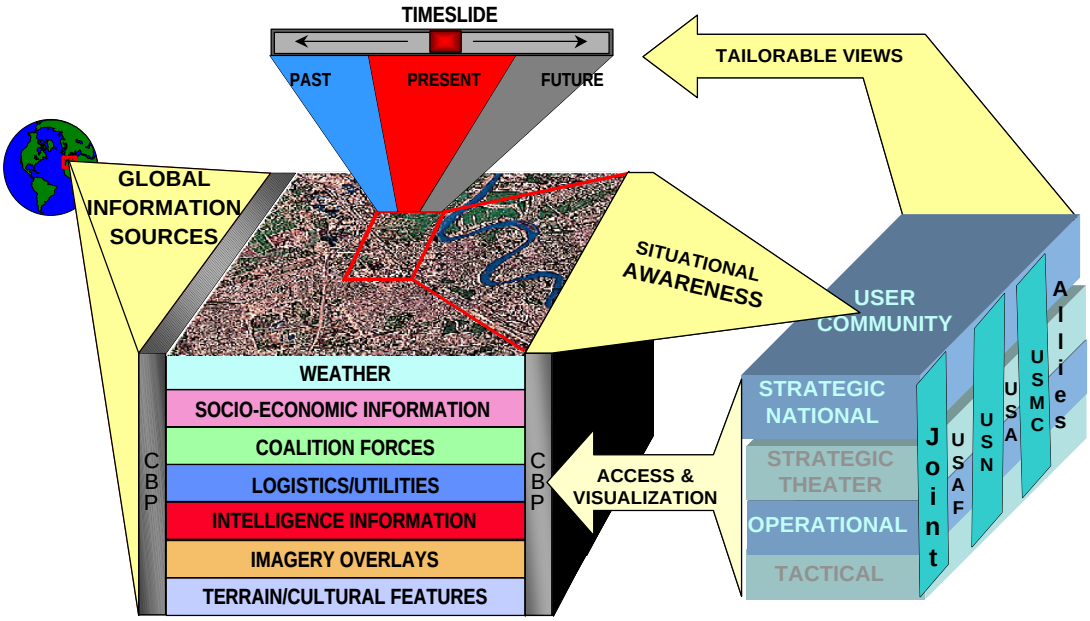

Figure 15: Consistent Battlespace Picture[4]

The goals of the Consistent Battlespace Picture ITTP are to: develop an information baseline consisting of integrated, fused, accurate, real-time, consistent, and relevant data that can be accessed, analyzed and visualized; and, provide decision-makers the ability to make better informed, accurate, dynamic decisions through information representing the entire battlespace picture.

The capabilities required are to: access and fuse all-source data; access and visualize complete, current, accurate information and assess multiple aspects of battlespace; assemble layered geocoordinated data (must ensure that specific points of interest are accurate); "drill-down" on specific AOI/AOR[5]; assure security, seamlessness and interoperability; and provide adaptable data formats.

The technologies that have been identified as crucial to achieving a consistent battlespace picture and require AF S&T investments are fusion; conflation (map accuracy); database access, storage and retrieval; multi-sensor exploitation; fused information management; expert systems technology; and, complex multi-sense[6] information presentation.

4.4 *Defensive Information Warfare ITTP*

Given the increasing reliance on reliable information to the Battle Manager, Defensive Information Warfare will play a pivotal role in tomorrow's battle plans. Figure 18 illustrates the environment of defensive information warfare and its intended capabilities.

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[4] The predominate method to which the information will be collected, processed and disseminated will be by spaceborne platforms.

[5] AOI/AOR stands for Area of Interest and Area of Responsibility.

[6] The goal would be for the Battle Manager to be able to hear, see, touch, and smell the N-dimensional battlespace environment.

The goals for the Defensive Information Warfare ITTP are to develop and demonstrate technology that allows for:

a) building in appropriate survivability, self protection and self healing features;
b) planning defensive courses of action;
c) preemption or denial of hostile offensive capabilities;
d) conducting network surveillance;
e) providing information attack warning and information attack assessment;
f) containing, denying, or destroying information attacker(s); and,
g) assessing damage and recover/reconstitute capabilities.

Figure 18: Defensive Information Environment

The capabilities required to achieve a defensive information warfare concept are:

a) Protect: defensive information operations planning (Pre-emptive Capabilities) and Tactical Indications and Warning (I&W);
b) Detect: be able to detect a real-time attack
c) React: attack assessment and response

The technologies required and will involve AF S&T investments are survivable information systems; vulnerability assessment/risk management; Information Operations (IO) sensors; damage assessment, recovery and forensics; COTS security; planning, awareness and decision support.

4.5 ***Global Grid ITTP***

The Global Grid concept is shown in Figure 19. The Global Grid will allow "virtual" communications anywhere, anytime and the capability to pass any data anywhere throughout the complete N-dimensional battlespace.

Figure 19: Global Grid Environment

The goals of the Global Grid ITTP are en-route connectivity; reachback for real-time C2; global interoperability; and, providing global connectivity to the Configurable Aerospace Command Center (CACC).

The capabilities required to achieve a true global grid are en-route mission planning; in-transit visibility; telemedicine[7]; situation awareness; and coalition operations.

The Global Grid ITTP has determined the following technologies will require AF S&T investments are: end-to-end technology enhancements; airborne SATCOM access; air-to-air LAN; reachback connectivity; seamless network integration; link and global resource management; and, aggregated information flow and services.

4.6 ***Real-Time Sensor to Shooter ITTP***

Under the Precision Strike ITT, the Real-time Sensor-to-Shooter ITTP top-level concept is shown in Figure 20. To achieve the concept, AFRL/IF depends on other AFRL Directorates, as shown in Figure 21. Each AFRL Directorate brings its respective expertise with the end goal of developing a synergistic approach to a real-time sensor-to-shooter capability.

[7] Telemedicine is the ability for real-time monitoring of all individuals operating within the battlespace.

The goal of the Real-time Sensor-to-Shooter ITTP is to provide a near real-time operation between sensors, decision maker(s), shooters, and weapons to address time critical targets.

To achieve the stated goal there must be a seamless, near real-time connectivity from the sensors[8] to the Battle Manager down to the shooters and their weapons.

The Real-Time Sensor-to-Shooter ITTP has determined the following technologies require AF S&T investments: real time information fusion in and out of the cockpit and in-cockpit route planning; real-time targeting, mission planning, replanning, and command loop; real-time weapons interface for Battle Damage Assessment (BDA); and an intelligent human interface.

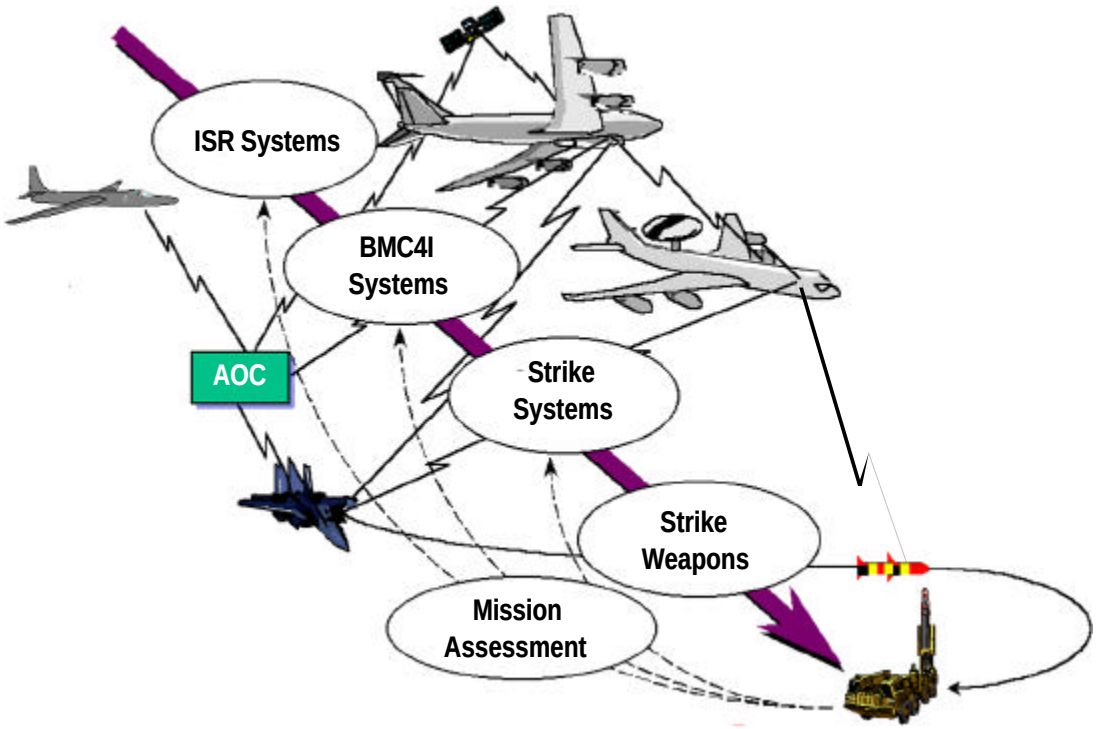

Figure 20: Elements of Real-time Sensor to Shooter

[8] Spaceborne assets will be the predominate platform for executing sensor-to-shooter operations.

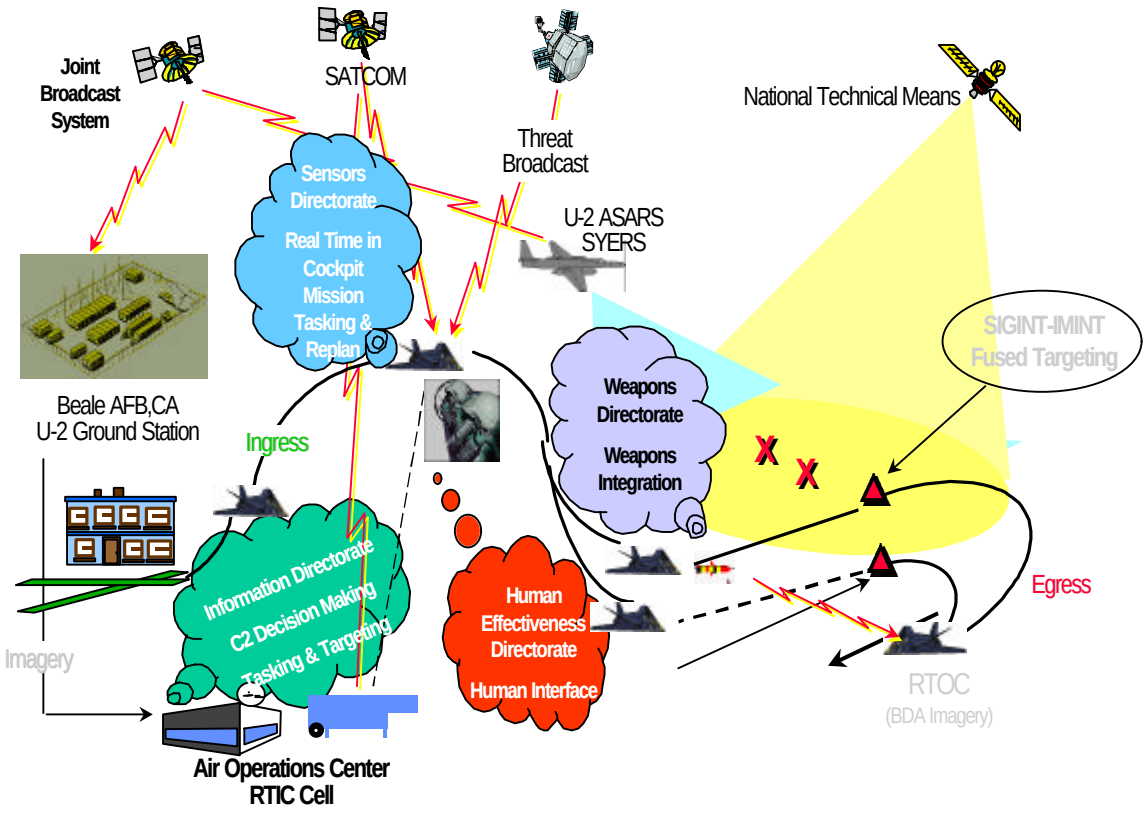

Figure 21: AFRL Involvement in Real-time Sensor-to-Shooter

5. **Summary**

This paper provided a top-level overview of the Air Force Research Laboratory's Information Dominance Integrated Technology Thrust efforts. To achieve the vision of Information Dominance, AFRL/IF has a three pronged approach, namely Global Awareness, Dynamic Planning and Execution, and Global Information Exchange. To provide a total synergistic approach to achieving its vision and goals, AFRL has created six Integrated Technology Thrust Programs: Configurable Command Center, Dynamic Command and Control, Consistent Battlespace Picture, Defensive Information Warfare, Global Grid and Real-time Sensor-to-Shooter. The goals, capabilities and required technologies of each were discussed. Hopefully, the reader will get a complete picture of how these C2 efforts will allow the warfighter to have Full Spectrum Dominance of the N-dimensional battlespace.